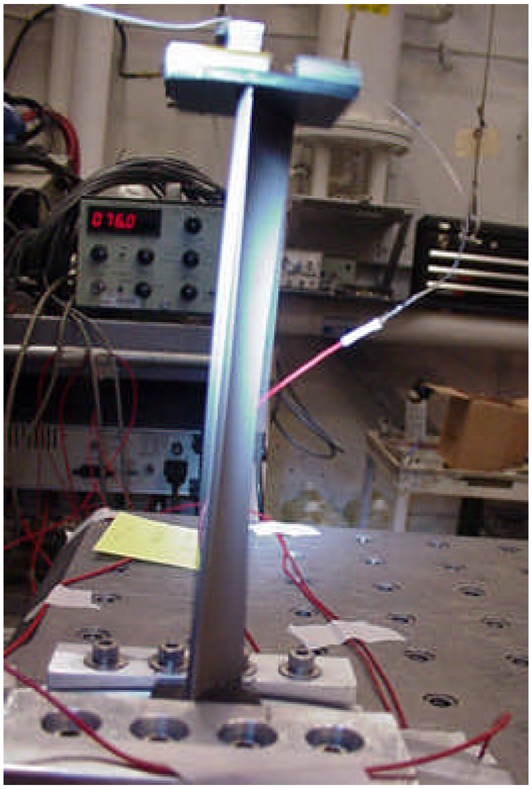
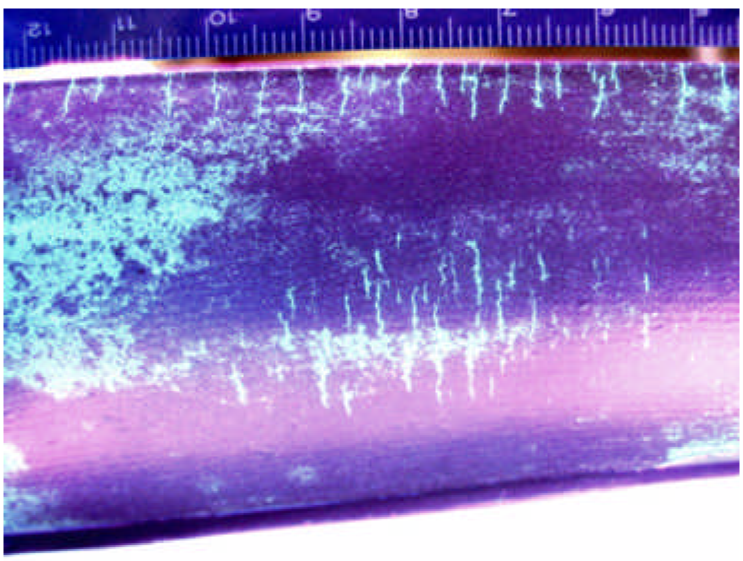
High-Frequency Testing of Composite Fan Vanes With Erosion-Resistant Coating Conducted



Coated vane undergoing vibratory testing with displacement amplitudes visible in photograph shadowing. Total vane height is approximately 15 cm (6 in.).



Trailing edge and convex midsection cracks visible with fluorescent dye after 10 million cycles at a strain amplitude of 1300 to 1400 me*. The scale marker is in centimeters. Maximum crack length is about 0.7 cm on the edge and 1.8 cm in the midsection.*

The mechanical integrity of hard, erosion-resistant coatings were tested using the Structural Dynamics Laboratory at the NASA Glenn Research Center. Under the guidance of Structural Mechanics and Dynamics Branch personnel, fixturing and test procedures were developed at Glenn to simulate engine vibratory conditions on coated polymer-matrix-composite bypass vanes using a slip table in the Structural Dynamics Laboratory. Results from the high-frequency mechanical bench testing, along with concurrent erosion testing of coupons and vanes, provided sufficient confidence to engine-endurance test similarly coated vane segments. The knowledge gained from this program will be applied to the development of oxidation- and erosion-resistant coatings for polymer matrix composite blades and vanes in future advanced turbine engines.

Fan bypass vanes from the AE3007 (Rolls Royce America, Indianapolis, IN) gas turbine engine were coated by Engelhard (Windsor, CT) with compliant bond coatings and hard ceramic coatings. The coatings were developed collaboratively by Glenn and Allison Advanced Development Corporation (AADC)/Rolls Royce America through research sponsored by the High-Temperature Engine Materials Technology Project (HITEMP) and the Higher Operating Temperature Propulsion Components (HOTPC) project. High-cycle fatigue was performed through high-frequency vibratory testing on a shaker table.

Vane resonant frequency modes were surveyed from 50 to 3000 Hz at input loads from 1g to 55g on both uncoated production vanes and vanes with the erosion-resistant coating. Vanes were instrumented with both lightweight accelerometers and strain gauges to establish resonance, mode shape, and strain amplitudes. Two high-frequency dwell conditions were chosen to excite two strain levels: one approaching the vane’s maximum allowable design strain and another near the expected maximum strain during engine operation. Six specimens were tested per dwell condition. Pretest and posttest inspections were performed optically at up to ×60 magnification and using a fluorescent-dye penetrant.

Accumulation of 10 million cycles at a strain amplitude of two to three times that expected in the engine (approximately 670 Hz and 20g) led to the development of multiple cracks in the coating that were only detectable using fluorescent-dye penetrant inspection. Cracks were prevalent on the trailing edge and on the convex side of the midsection. No cracking or spalling was evident using standard optical inspection at up to ×60 magnification. Further inspection may reveal whether these fine cracks penetrated the coating or were strictly on the surface.

The dwell condition that simulated actual engine conditions produced no obvious surface flaws even after up to 80 million cycles had been accumulated at strain amplitudes produced at approximately 1500 Hz and 45g.

Find out more about this research:
Structural Mechanics & Dynamics Branch http://structures.grc.nasa.gov/5930/

Polymers Branch http://www.grc.nasa.gov/WWW/MDWeb/5150/Polymers.html

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